A STUDY OF CHLOROAMINE

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Otis Avery Barnes

ENTITLED A Study of Chloroamine

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

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The writer takes this opportunity of expressing his appreciation to Professor W. F. Monfort, for the encouragement and many suggestions so willingly and courteously extended.

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TABLE OF CONENTS.

A STUDY OF CHLOROAMINE.

Introduction. The study of chloramine has not as yet received the attention from scientific investigators which the results from its use would naturally invite. The action of chloroamine seems to be closely allied to that of calcium hypochlorite and liquid chlorine, the exception being that it has apparently much greater sterilization value than either of the others. So without intending to disparage the use of the latter two which have been used for so long in water works practice, the present investigation was undertaken.

Calcium hypochlorite or bleach as it is commonly called and liquid chlorine have been used for a considerable length of time in water purification. It is a commonly accepted explanation among chemists that the antiseptic and bleaching action of chlorine or bleach lies in its oxidizing power. This power can best be illustrated by the following equations:

$$CaOCl_2 + HCl = CaCl_2 + HClO.$$

$$Cl_2 + H_2O \rightleftarrows HCl + HClO.$$

The hypochlorous acid thus formed is very unstable and may decompose as follows, liberating oxygen:

$$HClO \rightleftarrows HCl + O.$$

While the oxidizing and bleaching action of hypochlorite may correctly be attributed to this oxygen which is liberated in the nascent state; its germicidal power~~s~~ has an entirely

different explanation, as will be shown farther on.

Rideal[8] found that when chlorine was introduced into sewage that it was rapidly consumed, but that after free chlorine had entirely disappeared, there still existed a strong germicidal power. It was also found after a series of experiments that the same results were true when bleach was introduced into a water containing a small amount of dissolved ammonia.

It seems very probable that the ammonia does not increase the oxidizing activity of the chlorine. Readily oxidizable organic matter in water absorbs much less chlorine from ammonia and hypochlorite than from the hypochlorite alone. If the oxidizing activity were increased by the introduction of ammonia the reverse would be true. Rideal[8] also used the bleaching effect on dyestuffs as a means of obtaining some idea of the relative oxidizing action of the two, since in almost all cases bleaching is due to oxidation. Results showed that ammonia and bleach possessed only two per cent of the original bleaching or oxidizing action of the hypochlorite alone. Hence the enhanced germicidal value could not be due to oxidation.

While chloroamine has little oxidizing value, it still retains the property of displacing iodine from potassium iodide, giving the usual reaction with starch.

$$2KI + H_2SO_4 + NH_2Cl = K_2SO_4 + NH_4Cl + I_2.$$

The chlorine[6] can also be precipitated with silver nitrate and the ammonia determined by the colorimetric method with Nessler's reagent.

When ammonia and hypochlorite are mixed together there are several competing reactions which may take place and which depend on the strength of the solutions used. In the first place the reaction which one would naturally suspect of taking place is as follows:

$$CaOCl_2 + 2NH_4OH = Ca(OH)_2 + NH_4Cl + NH_4ClO.$$

The explanation that is now generally accepted for the effectiveness of NH_4ClO which is much greater than that of other hypochlorites, is that it is unstable and decomposes giving the following products:

$$NH_4ClO = NH_2Cl + H_2O.$$

So far the literature gives no specific test for chloroamine, and though the evidence which we have for its formation is only circumstantial, yet it is apparently conclusive and so far is universally accepted.

S. Rideal[8] has shown that NH_2Cl has a carbolic acid coefficient three times that of chlorine which is 2.2. Its germicidal property is also three times as great as that of other hypochlorites. It is pungent in odor, and is quite soluble in water.

Determinations by Rideal[8] of free and saline ammonia in the formation of NH_2Cl showed that the ammonia was only partially decomposed by the chlorine, and that only under special and unusual conditions did complete decomposition take place into HCl and N_2.

Ordinarily, NH_2Cl is formed. With more ammonia, however, its pungent odor disappears and hydrazine N_2H_4 is formed

which is a strong base, and also has weak germicidal properties. (0.24 carbolic coeffieient). Its salts are neutral and inodorous. With varying amounts of NH_3 the following reactions may occur:

(1) $NH_2Cl + NH_3 = N_2H_4Cl.$

(2) $NH_2Cl + 2NH_3 = N_2H_4 + NH_4Cl.$

(3) $3NH_2Cl + 2NH_3 = N_2 + 3NH_4Cl.$

According to Rideal[8], an evolution of nitrogen occurs in all cases. This being true, it is evident that the above reactions occur in small amounts, even when the theoretical correct amounts of bleach and ammonia are used. The three equations shown, however, are favored by an excess of ammonia.

According to Dakin[2] the germicidal value of hypochlorite in sewage is due to chloroamine derivatives produced by the action of chlorine on amino acids and proteins. If we think of ammonia as having the formula H_2NH, we can think of chloroamine being formed as follows:

$H_2NH + HClO = H_2NCl + H_2O.$

The proteins which the sewage contains, also possess -NH groups which react the same way to form compounds of the chloroamine group, that is compounds having the -NCl radical. It is not improbable, since they are proteins present in the living cell, that the killing of microorganisms by hypochlorites is due to chemical changes brought about in some of the compounds of the living cell; either by direct action of the antiseptic, or by action of products formed from the antiseptic by combination with substances in the medium in which the organisms are suspended. Hence hypochlorites would be expected to act on both intra and

extra cellular proteins.

Hence, when chlorine or bleach is added to sewage, a rapid absorption first takes place due for the most part probably to oxidation of readily oxidizable organic matter, and secondly to the formation of toxic chloroamine compounds from the amino acids and proteins. After this first rapid absorption, free chlorine will have almost entirely disappeared.

On the other hand when chloroamine is added, such an initial rapid absorption can not take place, since the chlorine is now combined and can act no longer by oxidation. The germicidal action, however, is very much greater since all of its chlorine is saved, and the period of its action is also increased.

According to Dakin[2], the germicidal qualities of chloroamine is due in part to the properties of its molecule as a whole, and also to the action of the active halogen within. The chloroamine reacts with amino acids like hypochlorite. The chlorine evidently showing a greater preference for the heavier nitrogen molecule.

$$H_2NCl + \underset{\text{(glycine)}}{CH_2(NH_2)COOH} = CH_2(NHCl)COOH + NH_3.$$

The hydrogen of the -NH or $-NH_2$ groups being replaced by chlorine, so that the halogen becomes directly linked to nitrogen as in chloroamine itself. Some of the germicidal value may be due to the fact that many of the constituents of living organisms contain nitrogen in a form capable of attracting chlorine from chloroamine. Some may be due to an obscure special action of the chloroamine molecule as a whole, or possibly to selective chlorination of particular cell constituents.

W. A. Noyes (Director of U. of I. Chemical Laboratories) has suggested that the antiseptic action of chlorine may be due to positive chlorine. It will be noticed that chlorine is apparently positive in all of its germicidal compounds.

EXPERIMENTAL.

Preparation of Solutions. The first thing to do in an investigation of this kind, is to obtain material and solutions with which to work. So solutions of bleaching powder and ammonia were made up.

The solution of hypochlorite was made from a bleaching powder put up for Brookman Manufacturing Company of Chicago, Illinois, and being supposedly 30% pure. The bleach was mixed with distilled water and shaken thoroughly for several hours with a shaking machine. The solution was then filtered and an analysis made to determine the amount of available chlorine.

The method used was to take a 25cc sample and add an excess of N/10 arsenious acid solution. The reaction involved is:

$$H_3AsO_3 + Cl_2 + H_2O = H_3AsO_4 + 2HCl.$$

The excess H_3AsO_3 was then titrated with N/10 iodine solution which had been standarized back to N/10 $K_2Cr_2O_7$ through N/10 $Na_2S_2O_3$. The N/10 $K_2Cr_2O_7$ was originally standarized against anhydrous $FeSO_4$.

With 25gms. of Brookman bleach in a liter of water, a solution was obtained containing 2.3 gms. available chlorine per liter. This was then diluted so that the solution contained 2 gms. of available chlorine per liter of solution.

A solution of aqua ammonia was then prepared, so that the ammonia contained in a liter of solution was 1 gm. The determination of its strength was made by standardizing through H_2SO_4 solution against anhydrous Na_2CO_3.

Action of Chloroamine on Bacteria.

Crenothrix. Crenothrix is a true bacteria (Eubacteria), and is one of the so called iron bacteria, a media rich in iron being apparently necessary for its maintainance of life. Its cylindrical cells are united together in unbranched threads. These threads which gradually enlarge towards the free end, are covered with a thick sheath, which becomes infiltrated with the hydroxide of iron to which it owes its characteristic color of iron rust. Reproduction takes place by the formation of round gonidia. According to Winogradsky[11] the iron bacteria take up the iron from solution in the ferrous state and obtain their energy by oxidizing it to the ferric state, which later appears in the form of iron rust deposited in the sheath of the filaments.

Crenothrix is quite common in several sections of the State of Illinois. In fact it is entirely too common in some districts, especially so in the cities of Champaign-Urbana. Here it has developed so abundantly in the reservoirs (1917), that the water supply is almost unfit for drinking or for certain industrial purposes. It also promises to cause considerable trouble, by gradually filling up the pipes and conduits of the water circuit.

Experiments were carried out to determine the effective-

ness of chloroamine on crenothrix. So far the literature gives no media upon which crenothrix will grow. So it was not possible to plate out and make a bacteriological count to determine the effectiveness of chloroamine. According to Oskar Rossler[10], crenothrix can be made to grow on porous porcelain in a water solution containing $FeSO_4$, 1 in 5000.

Race[5], who tried various amounts of ammonia and bleach, found that the highest efficiency was obtained with the least amount of decomposition when available chlorine and ammonia were in exact proportions required by the formula NH_2Cl. This required two parts by weight of available chlorine and one part by weight of anhydrous ammonia.

Chloroamine was first tried on 800 cc of the University of Illinois tap water. Four bottles were taken, and the experiment run in duplicate. To two of these, ammonia and chlorine were introduced in quantities sufficient to furnish 1.0 ppm. (mg. per liter), available chlorine, in the above ratio. The four bottles were loosely corked, the other two being kept as blanks or control tests. The bottles were then placed on a shelf in a medium strong light. The bottles were examined frequently and at the end of one week the two blank or control bottles showed an abundant reddish growth on the bottom. The other two, however, which were treated, showed no visible growth of any kind.

The action of chloroamine was then carried farther and compared with the action of hypochlorite. University tap water was used as before, but this time bottles having a capacity of eleven liters were used. Five tests were carried out. One bottle was

kept for control observation without any treatment. To a second, bleach solution was added to furnish 1 ppm. of available chlorine. To the third, fourth and fifth respectfully, chloroamine was added in the ratio to give 0.5, 0.75 and 1.0 ppm. of chlorine.

The control bottle showed a heavy reddish-brown growth on the bottom at the end of one week. The others showed no growth, but there was a light flesh colored deposit on the bottom, which was probably $CaCO_3$, $Fe(OH)_3$, or $Fe_2(CO_3)_3$, and may have been precipitated by the dissolved CO_2 in the water upon the addition of the bleach.

The other bottles were kept for a while to see if there would appear any of the so called aftergrowth. At the end of a three weeks time the bottle treated only with bleach began to show a velvety growth, and on standing another week, the growth was quite pronounced and had a reddish-brown lustre. Samples of this growth and of the growth in the control bottle were examined under the microscope and found to have the characteristics of crenothrix. The method used was to take a little of the suspended growth on a slide, protect with a cover glass, focus the microscope, and examine. Then a little dilute HCl was introduced on the slide, and as the acid dissolved the sheath of $Fe(OH)_3$ the structure was brought out much more clearly. The characteristic crenothrix structure is shown below. The growth from the two bottles showed this characteristic structure.

Crenothrix.
A characteristic colony
of filaments composed of
rod shaped cells.

2

The other three bottles showed absolutely no growth even after six months time. However, the sediment which had settled out on the bottom did shrivel and roll up like scars. This was probably due to jarring and to no action taking place within the solution. This sediment, when examined, showed no evidence of crenothrix growth.

Probably the reason there was no growth following sterilization by chloroamine, was because it was not largely used up through oxidation reactions as in the case of bleach; and nearly all of the added available chlorine was retained for the destruction of the crenothrix and any other later growth which would result through sport formation.

Efforts were made to determine any odor or taste in the bottles following the death of the algae. The odor in the chloroamine bottles was rather pleasant as compared with that in the blank or in the hypochlorite treated bottle. Neither was there a taste that was at all offensive.There seemed to be a taste in the bottle treated with I.0 ppm. NH_2Cl probably due to the NH_2Cl itself,since a non-smoker notices an occasional taste in water treated with hypochlorite as low as 0.35 ppm..In the other two bottles.however,such a taste was not noticeable.

The above work was repeated and the same results were obtained. Chloroamine prevents the growth of crenothrix,a concentration of 0.5 ppm. being effective.The prevention is permanent,no growth appearing even after six months time. The chloroamine gave rise to no offensive odor or taste.

These results seem to be concurrent with those obtained by Race[5,6,7] and DeBerard[3],who,after overcoming certain difficulties

in methods of operation, found that chloroamine as low as 0.2 ppm. was effective; even when carried out practically on a 20,000,000 gallon plant, and besides allowed none of the aftergrowth which was so objectionable when other sterilizers were used. DeBerard, however encountered other difficulties in the use of NH_2Cl at Denver, and has abandoned it at that place for the present.

Methods of Making NH_2Cl.

Several methods were now tried to see if chloroamine could not be made on some cheaper plan.

Most all waters have two to three ppm. of nitrogen as ammonia nitrogen (NH_4Cl, $(NH_4)_2CO_3$ etc.). It was thought that the introduction of bleach to such waters might cause the formation of NH_2Cl, by such reactions as follows:

$$NH_4Cl + CaOCl_2 = CaCl_2 + NH_4ClO.$$

$$(NH_4)_2CO_3 + 2CaOCl_2 = CaCl_2 + CaCO_3 + 2NH_4ClO.$$

$$NH_4ClO = NH_2Cl + H_2O.$$

Also since the chlorine reacts with water as follows:

$$Cl_2 + H_2O = HCl + HClO.$$

there seems to be no reason why on the addition of ammonia the following should not take place:

$$NH_3 + HClO = NH_2Cl + H_2O.$$

The literature offers no available test for chloroamine, and so about the only way to test for its formation is to compare the effects on suspensions of a common bacteria, such as B.Coli..

Experiments were carried out as follows: Bacteriological tests were first carried out to determine the approximate concentration of NH_2Cl necessary to sterilize completely a 24 hour old culture of a vigorous strain of B.Coli.

A series of sterilized tubes were taken, and IO cc solutions of chloroamine in decreasing concentration were first prepared. Two drops were then taken from a 24 hour old culture of B.Coli growing in Standard Peptone Bouillon[IO], and suspended in IOO cc of sterile water. One cc of this suspension was then transfered to each tube, and after standing for ten minutes, one cc of each tube was transfered to a petri dish and plated out, using Standard Nutrient Agar[IO]. After standing for 24 hours at $37\frac{1}{2}^{\circ}$, a bacteriological count was made, and the results obtained showed that 0.5 ppm of NH_2Cl was the minimum below which absolute sterilization could not be certain.

A series of tubes were now prepared having IO cc of the following solutions; sterile water, chloroamine, bleach, NH_4Cl and bleach, and $(NH_4)_2CO_3$ and bleach. These were added so that there was $\frac{1}{2}$ ppm of available chlorine present in each case, and ammonia in correct proportion. To each tube B.Coli was now added as before, and each solution plated out on Agar.

The above was repeated several times, but the results varied considerably, so that it was impossible to draw any conclusion as to whether chloroamine was formed in any of the other cases or not. The mixture of ammonia and bleach, however, gave constant results, absolute sterilization being obtained with as high as 20,000 B.Coli per cc.

The latter set of experiments were repeated with the exception of the ones with NH_4Cl, $(NH_4)_2CO_3$, and bleach alone; this time with the express purpose of determining whether the length of time had much to do with the action of chloroamine. The tubes were run in duplicate, one tube of each set being inoculated with

B.Coli and allowed to stand for ten minutes, before plating out. The other tube of each set was inoculated, thoroughly mixed, and plated immediately; possibly a minute elapsing before this could be done. The results obtained were checked by verification with another similar set. It was found that in all cases where ammonia and bleach were used, absolute sterilization took place almost if not immediately. With the chlorine water and bleach, however, this was not true. While complete sterilization was accomplished by contact for the longer length of time, yet under shorter contact, satisfactory sterilization was not successful, the B.Coli count running as high as 340 with a blank of 1600 per cc. This evidence, while not conclusive by any means, would seem to indicate that the chloroamine was not formed by the action of ammonia on chlorine water. Its slower toxic action may have been due to the HCl present from the reactions:

$$Cl_2 + H_2O = HCl + HClO.$$

$$2HClO = 2HCl + O_2.$$

According to Bray & Dowell[1] some NH_2Cl is formed in this reaction, but this is only a very rapid primary reaction. The final follow up reaction results in its decomposition and the formation of NCl_3.

$$3NH_2Cl = N_2 + NH_4Cl + 2HCl.$$

$$\underline{3NH_2Cl + NH_4Cl = 3NH_3 + HCl + NCl_3.}$$

$$6NH_2Cl = N_2 + 3NH_4Cl + NCl_3.$$

Acids also cause the decomposition of the NH_2Cl, probably as follows:

$$3NH_2Cl + 2H^+ = NCl_3 + 2NH_4^+.$$

Race[45] has made chloroamine by the double decomposition in solution of $Ca(OCl)_2$ and $(NH_4)_2C_2O_4$.

$$Ca(OCl)_2 + (NH_4)_2C_2O_4 = CaC_2O_4 + 2NH_4ClO.$$

$$NH_4ClO = NH_2Cl + H_2O.$$

The calcium oxalate was then removed by centrifugalization.

Race[5] also tried to obtain NH_2Cl by mixing NH_3 and pure liquid chlorine, but was unsuccessful, probably (Race) because of the non-production of HClO by pure Chlorine and water, without which the formation of NH_2Cl is apparently impossible.

Efforts have also been made (Race[7]) to prepare chloroamine by the electrolysis of NH_4Cl, but so far efforts in this direction have been unsuccessful. Nitrogen trichloride, a heavy oily substance which is extremely unstable, and highly explosive being formed instead.

During the preceding work the author found it necessary to analyze the solutions of chlorine water, and bleach for available chlorine before each experiment. He found that the available chlorine in chlorine water depreciated rapidly. The solution that was originally made contained I.7 gms. per liter; while at the end of ten days it only had 0.8 gms. of available chlorine to the liter, or had deteriorated more than half. The bleach solution on the other hand was quite stable. In six months time it had changed from 2.0 gms. to I.8 gms. of available chlorine per liter.

Stability of Chloroamine Solution.

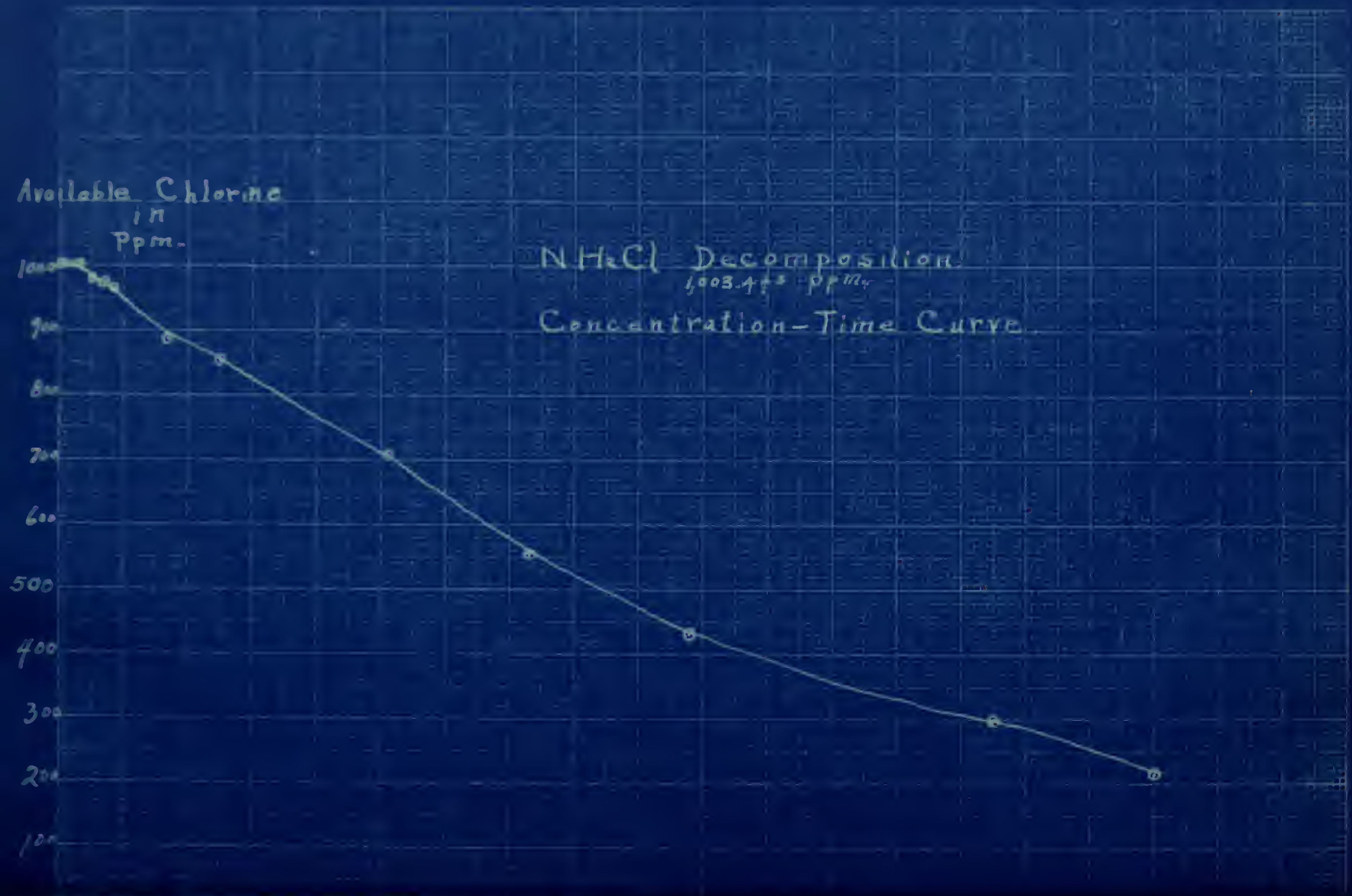
It was desirable to determine the stability of chloroamine solution, and determine if possible, whether the amount of nitrogen evolved is proportional to the rate of decomposition of the NH_2Cl. A solution of NH_2Cl was made up in the proper ratio, 2 of bleach to one of ammonia, of a strength sufficient to furnish I,000 ppm. The rate of decomposition was then determined at intervals by taking a definite volume of the sample and titrating with iodine solution, after reaction with an excess of arsenious acid.

The volume of nitrogen liberated from a definite volume of freshly prepared chloroamine solution of the same strength as the above was also determined at recorded intervals.

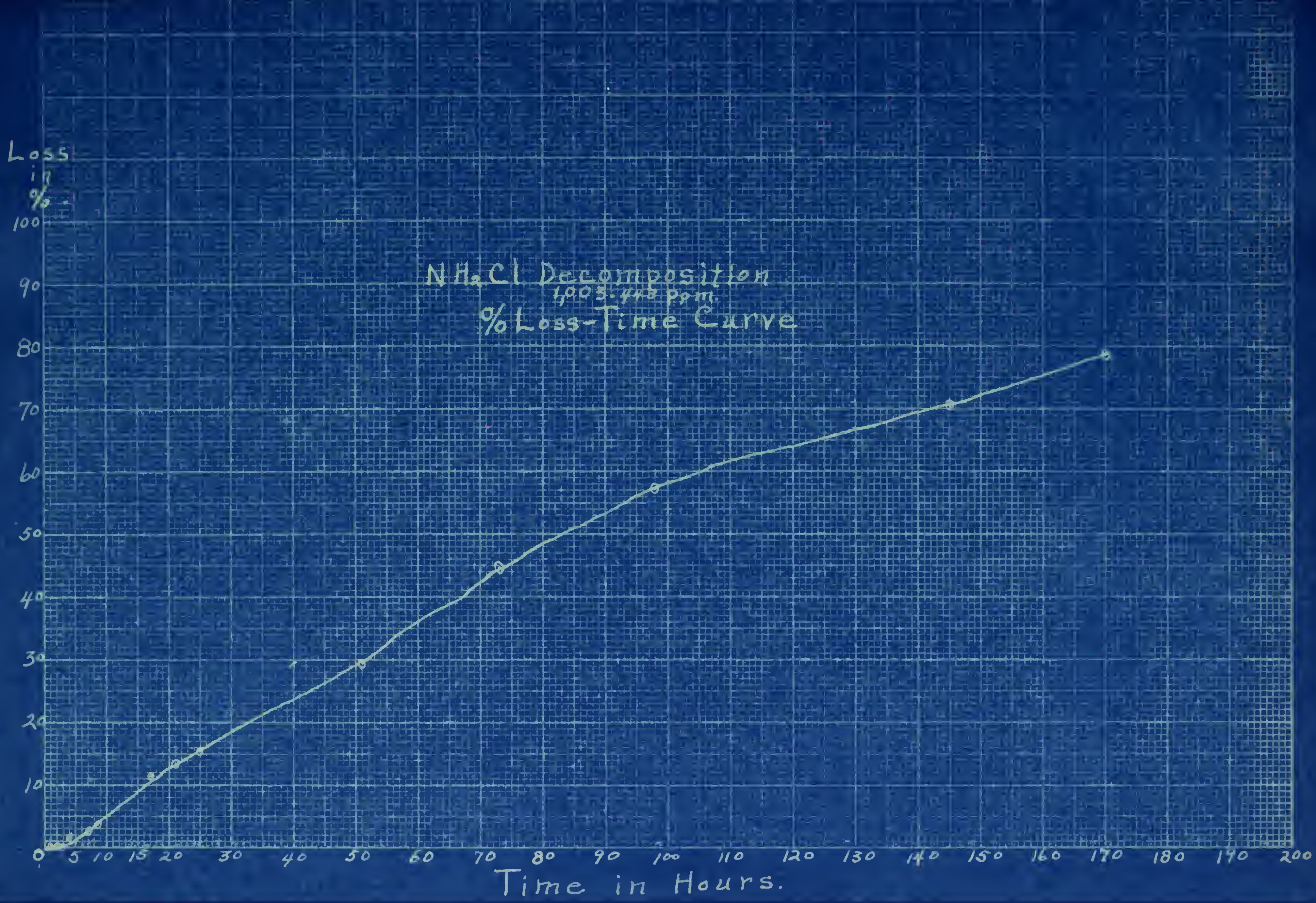
The first nitrogen determination was made in a closed burette, the solution being over mercury. It was thought that perhaps there might be some reaction between the mercury and chloroamine solution, which would vitiate the results. So the experiment was repeated, twice as much solution being taken, this time in a gas collecting bulb, and the gas evolved being forced over into a measuring burette over mercury. The results compared quite favorably with the first, the second being about twice the first in each case. The results follow:

Decrease in the Available Chlorine of a Chloroamine Solution.

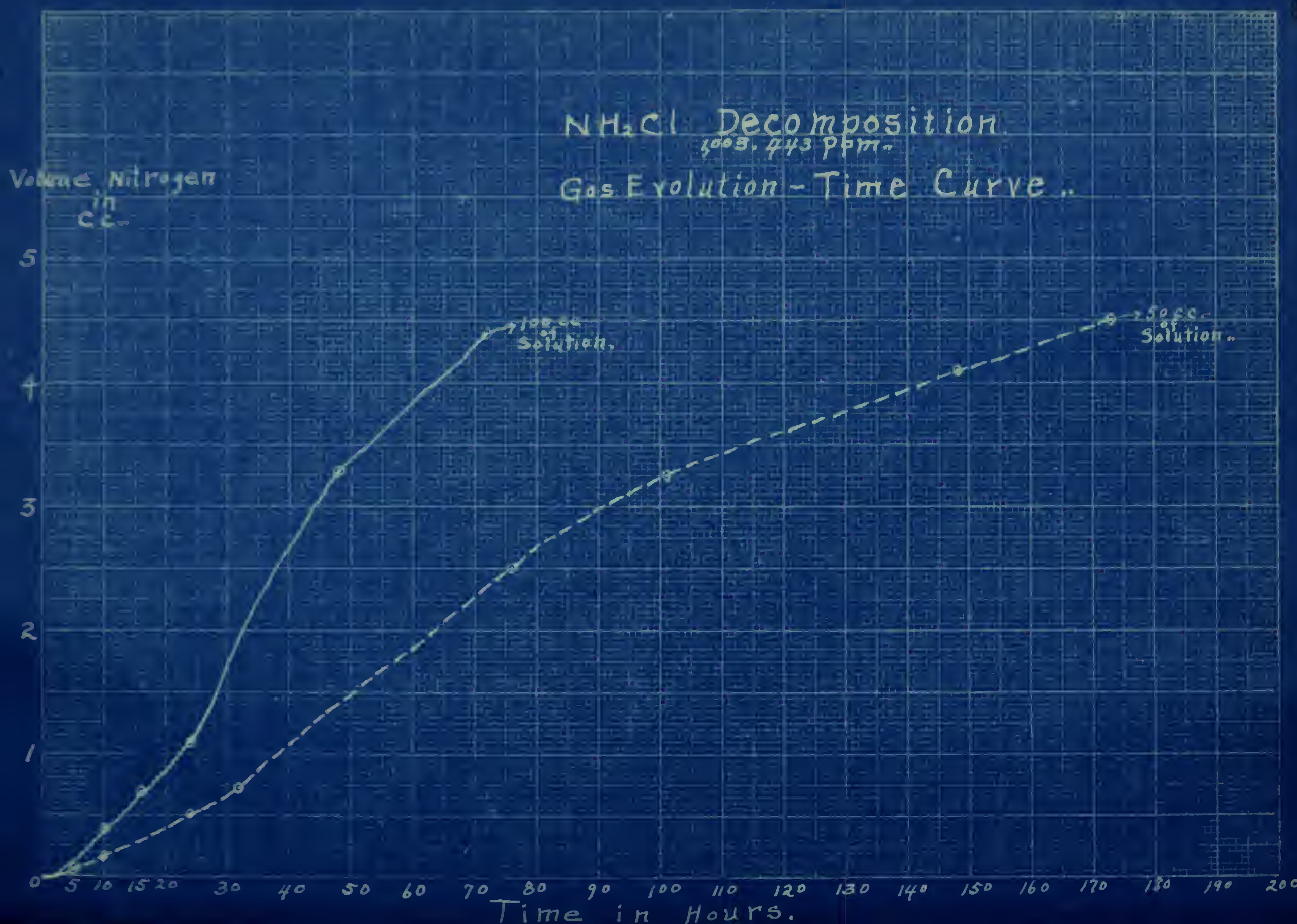
Hours.	Ppm.	Loss %.
0	1003.443	0
1	1003.443	0
2	1003.443	0
3	1003.443	0
4	984.68	1.87
5	980.86	2.25
7	975.12	2.82
8½	965.56	3.78
17	889.08	11.40
19	879.52	12.35
21	869.96	13.30
23	860.094	14.29
25	850.84	15.21
29	841.28	16.16
51	707.44	29.50
73	554.48	44.74
98	430.20	57.13
145	296.36	70.47
170	213.00	78.77



Available Chlorine in ppm.
NH2Cl Decomposition
1,003.4 ppm.
Concentration-Time Curve
1000
900
800
700
600
500
400
300
200
100



NH_4Cl Decomposition
1,003.448 p.p.m.
% Loss-Time Curve
Loss in %
100
90
80
70
60
50
40
30
20
10
0
5 10 15 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Time in Hours.


NH₂Cl Decomposition
1003.443 ppm.
Gas Evolution - Time Curve.
Volume Nitrogen in C.C.
100 cc. of Solution.
50 cc. of Solution.
Time in Hours.
0
5
10
15
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
1
2
3
4
5

Gas Evolved During the Decomposition of Chloroamine. (1003 ppm).

------50cc--------

Hours.	Gas.
1	0
2	0
3	0
4	0.01
5	0.05
6	0.09
7	0.12
8	0.15
10	0.17
11½	0.27
20	0.37
22	0.44
24	0.51
26	0.63
28	0.69
32	0.73
54	1.6
76	2.5
101	3.25
148	4.10
173	4.50

-----100cc--------

Hours.	Gas.
10	0.4
16	0.7
24	1.1
48	3.3
72	4.4

From the two curves it is seen that the amount of nitrogen evolved varies directly with the rate of disappearance of available chlorine. This is what one would naturally expect from the following equation:

$$3NH_2Cl = N_2 + NH_4Cl + 2HCl.$$

A series of determinations were now made to determine the rate of decomposition of solutions of chloroamine of different strengths. The data follows. It might be well to note here that in order to obtain bleach furnishing the stronger solutions, it was necessary to use a purer grade of hypochlorite. 80 grams of calcium hypochlorite put up for Henry Heil Chemical Company of St. Louis, Missouri, being dissolved in a liter of solution. This furnished a solution containing 20.4 gms. available chlorine to the liter.

Decomposition of Chloroamine Solutions.

	1		2	
Hours.	Ppm.	% loss.	Ppm.	% loss.
0	10200	0	8160	0
1	7275	28.68	7388	9.46
2	6900	32.35	7013	14.06
3	6413	37.13	6619	18.88
7	4875	52.26	5438	33.36
11	3844	62.31	4425	45.76
24	1744	82.90	2194	73.11
32½	1125	88.97	1819	77.71
53½	300	97.06	469	93.03

Decomposition of Chloroamine Solutions.(Cont.)

	--------3---------		--------4--------	
Hours.	Ppm.	% loss.	Ppm.	% loss.
0	6120	0	4080	0
1	5513	9.92	3750	8.09
2	5250	14.21	3638	10.83
3	4988	18.50	3516	13.82
7	4350	28.92	3169	22.33
11	3788	38.10	2897	29.00
24	2175	64.46	2016	50.59
32½	1538	74.87	1603	60.71
53½	563	90.80	863	78.85

	--------5-------		--------6--------	
0	3060	0	2040	0
1	2775	9.31	1875	8.09
2	2700	11.76	1844	9.61
3	2625	14.22	1813	11.13
7	2391	21.86	1706	16.37
11	2231	27.09	1638	19.71
24	1688	44.84	1350	33.82
32½	1397	54.35	1194	41.47
53½	853	72.12	863	57.69

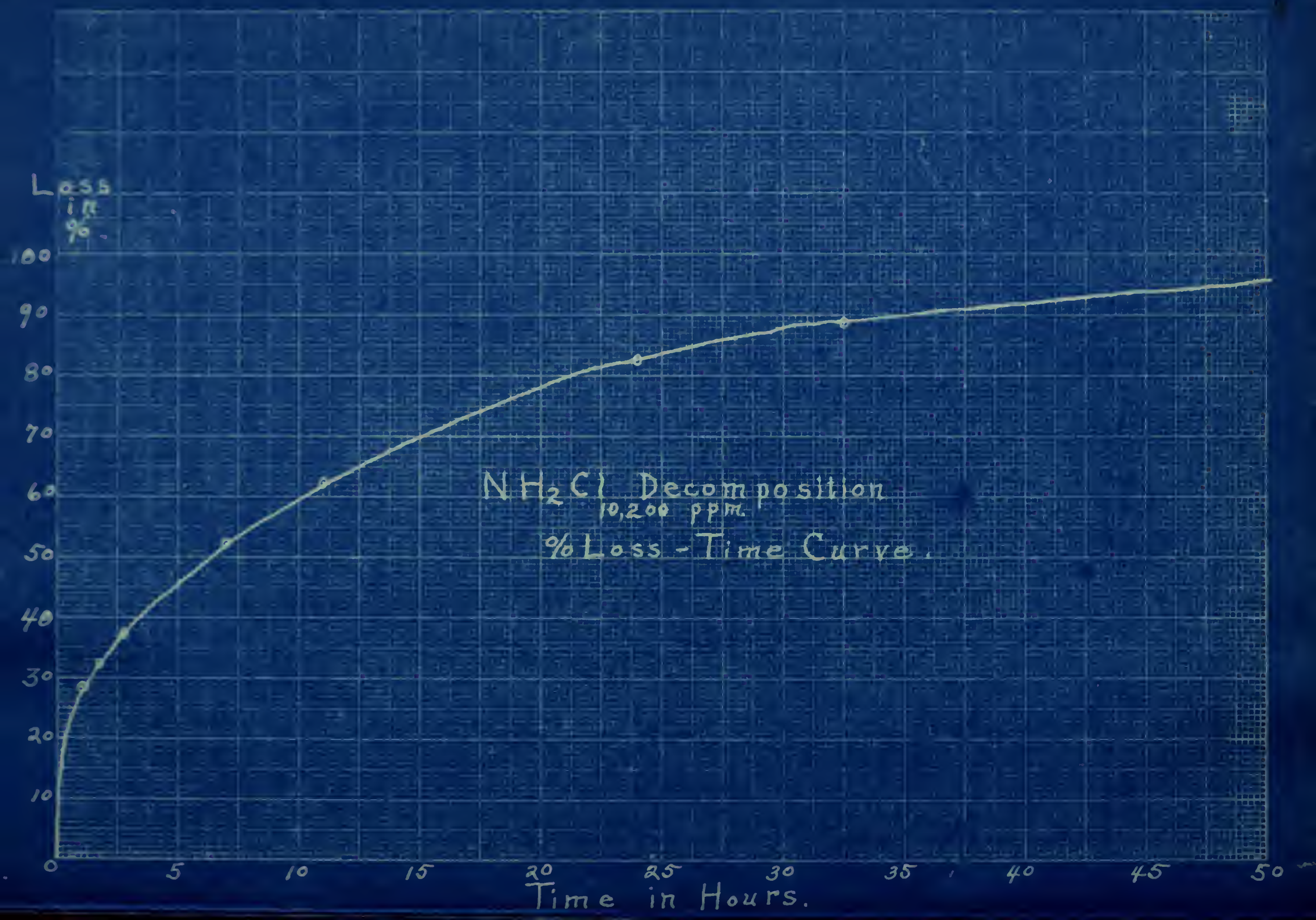
Number one foamed actively and much gas was evolved at the start; the evolution of nitrogen was also very active from two; number three gave off nitrogen somewhat quickly at first. Afterwards the gas was given off at a more moderate rate from these three, but always more rapidly than from any of the others. The less concentrated solutions gave off nitrogen during the experiment, but extreme gasing was not noticeable at the start, as with the others. A heavy precipitate of $Ca(OH)_2$ was thrown down in the first bottle, a smaller amount in the second etc., the precipitate decreasing with decreasing concentration.

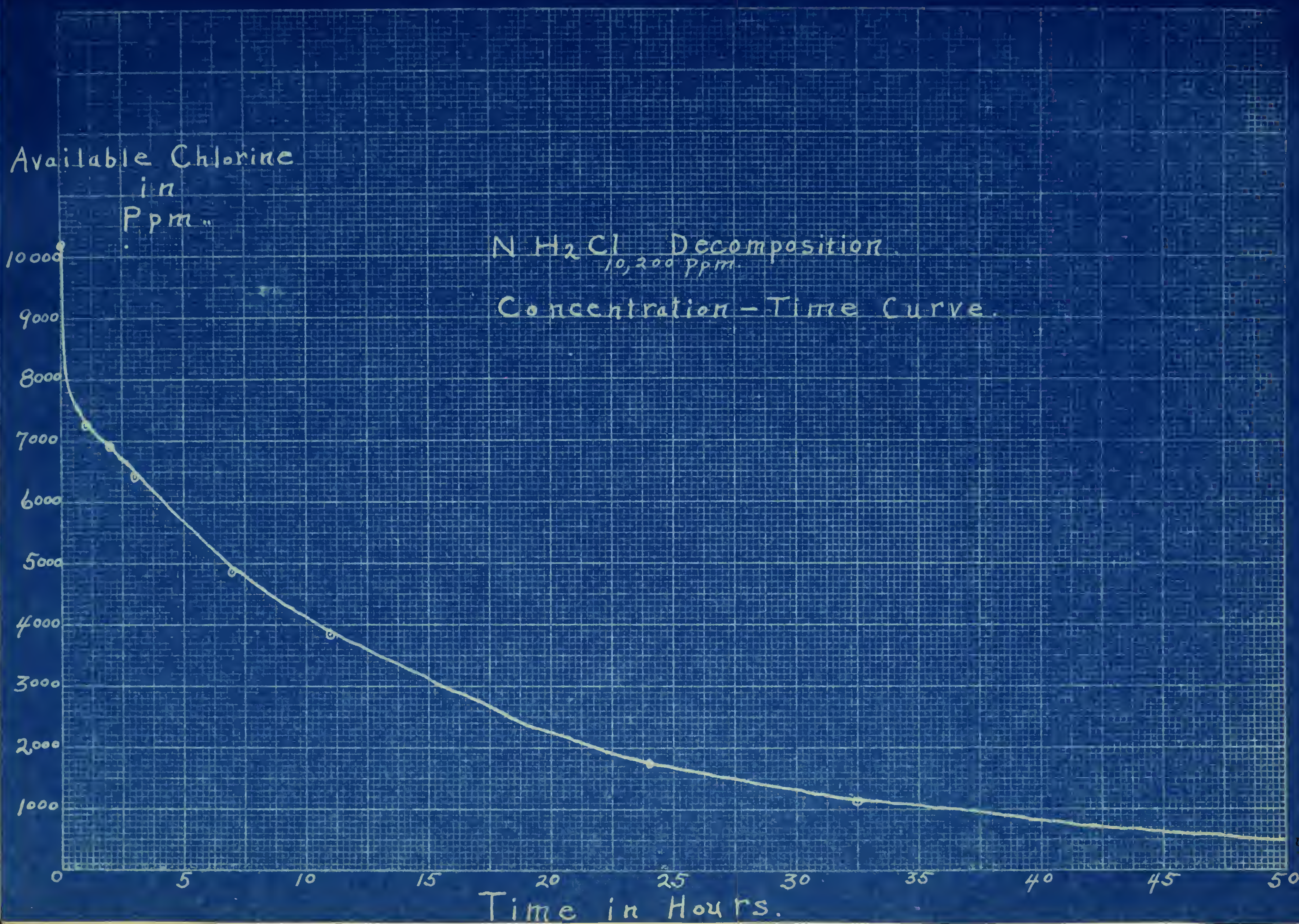
From the curves it would not seem feasible to mix up chloroamine, except in unusual cases, more than 24 hours in advance. Even then it is doubtful whether a concentration greater than 1000 ppm. should be exceeded. It will be noticed that with 2000 ppm. the loss is 1/3 of the available chlorine present, while with 1000 ppm. the loss is less than 1/6 or 15%.

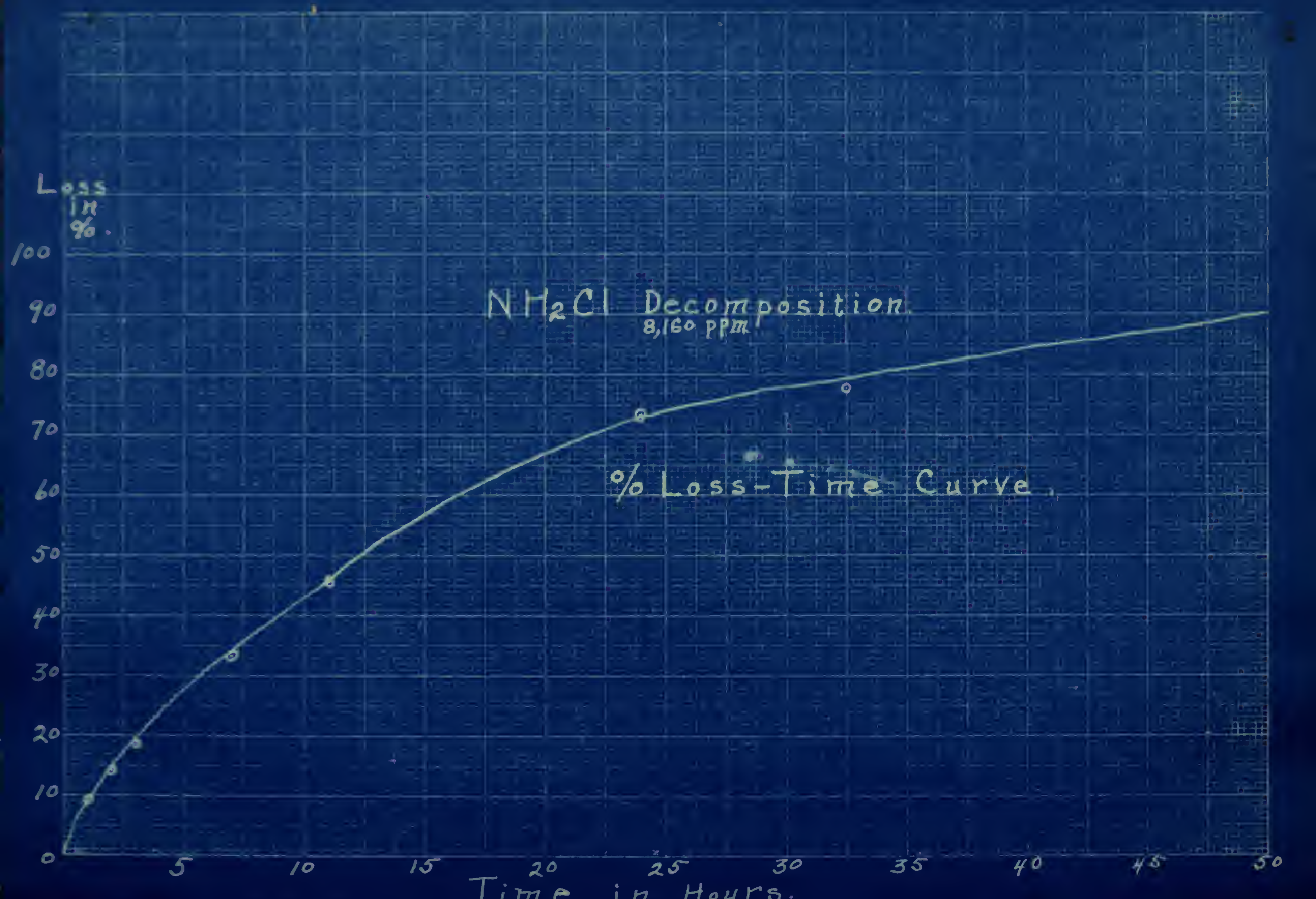
CONCLUSION.

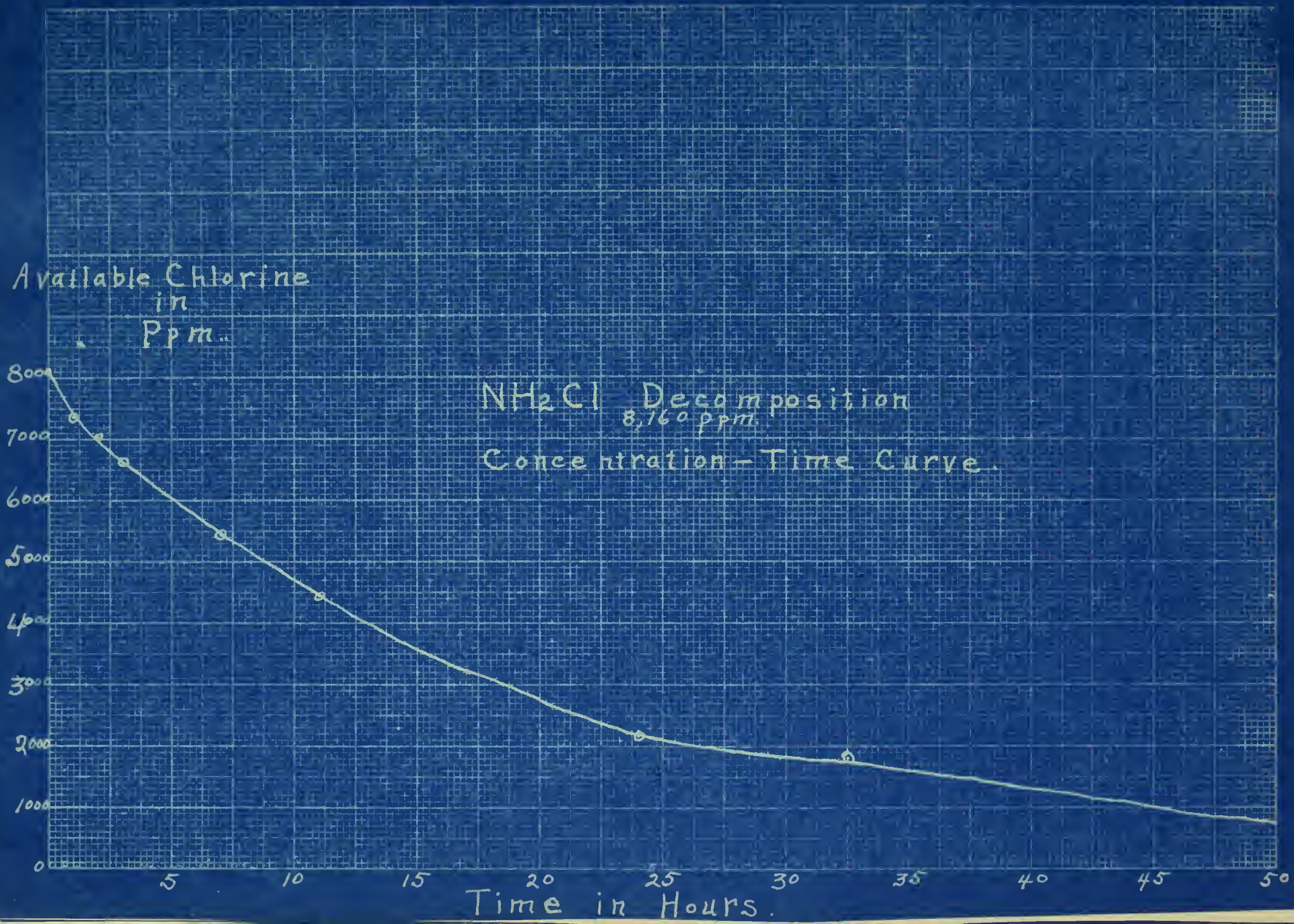
Chloroamine is most stable in dilute solutions. With more concentrated solutions a larger less of nitrogen and available chlorine occurs with every increase of concentration. Also if the highest efficiency is to be obtained, the chloroamine should be used as quickly after mixing as possible, thereby decreasing the loss of available chlorine through decomposition. It is doubtful whether a strength greater than 1000 ppm. of available chlorine should be mixed up in advance for use in water purification. Such solutions should be used up at least 24 hours after mixing.

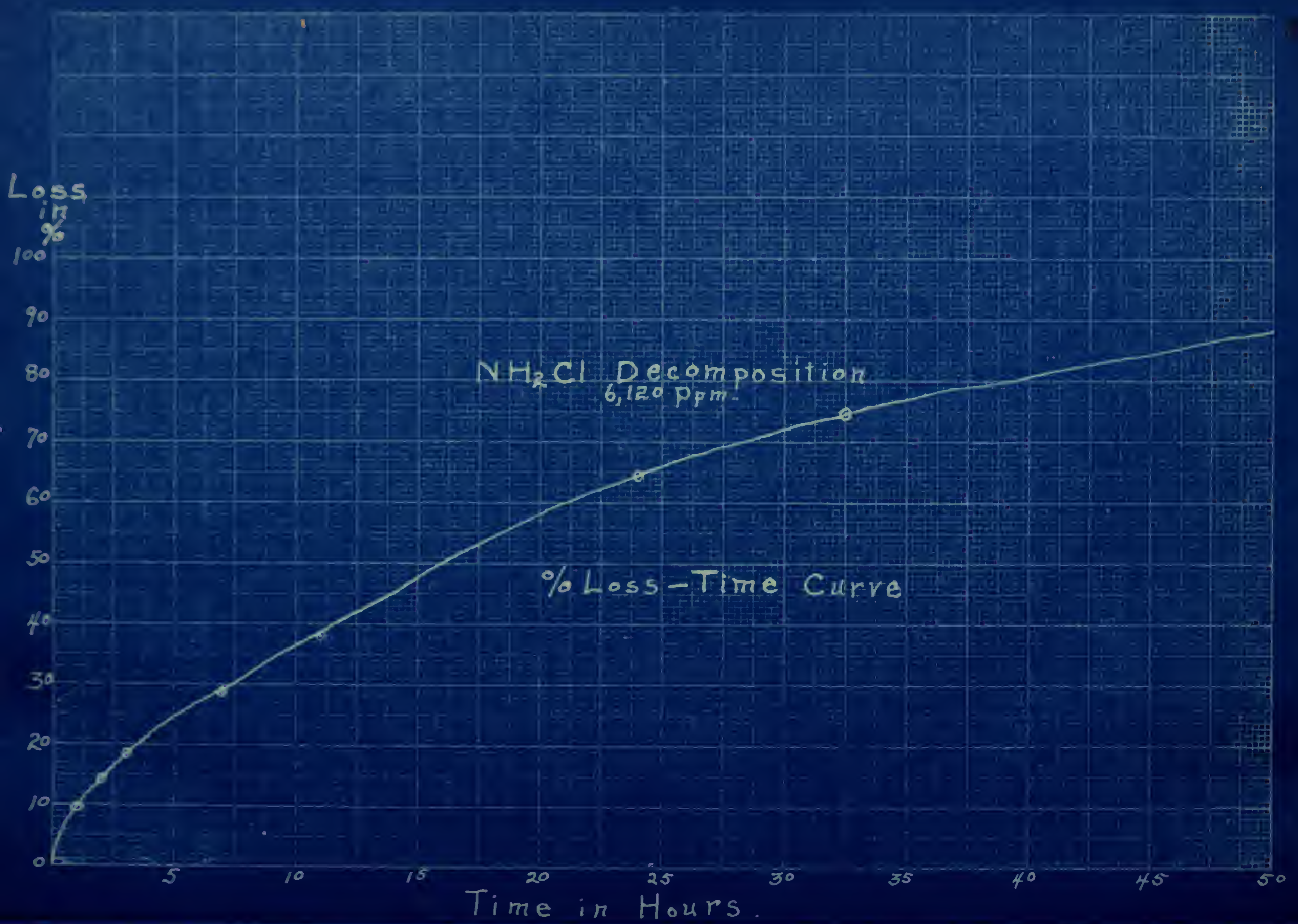
While no new methods of obtaining chloroamine were discovered, its effectiveness as a germicide and antiseptic was demonstrated beyond question. With B. Coli absolute sterilization took place. The troublesome iron bacteria, crenothrix, was also permanently prevented from growing; a concentration of 0.5 ppm. being sufficient, giving rise to no objectionable taste or odor. Anyone troubled with crenothrix growth is advised to treat their plant with a solution which will furnish this strength.


Loss in %
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
NH2Cl Decomposition
10,200 ppm.
% Loss - Time Curve.
Time in Hours.

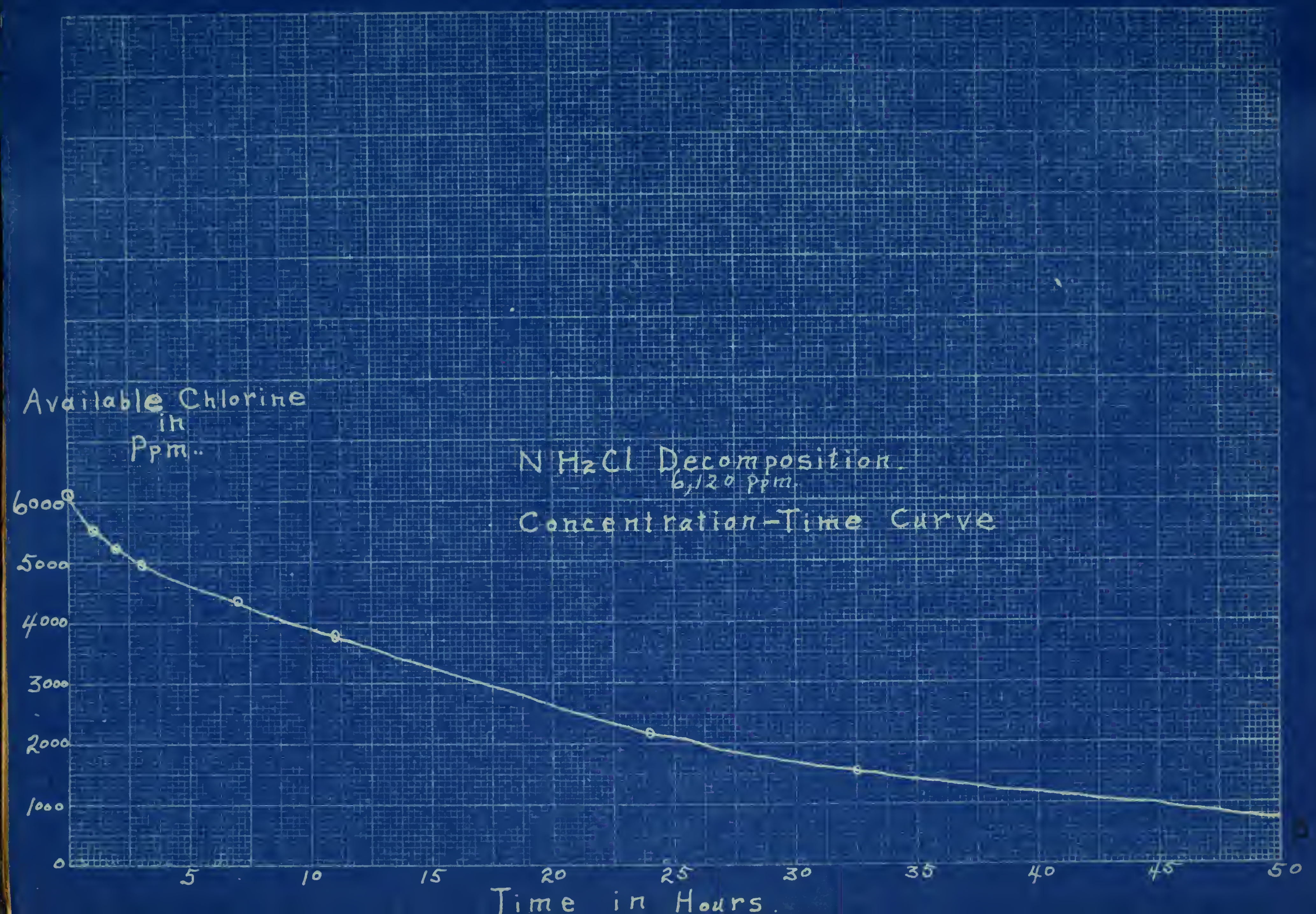

Available Chlorine
in
Ppm.
NH_2Cl Decomposition
10,200 ppm.
Concentration – Time Curve.
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50
Time in Hours.

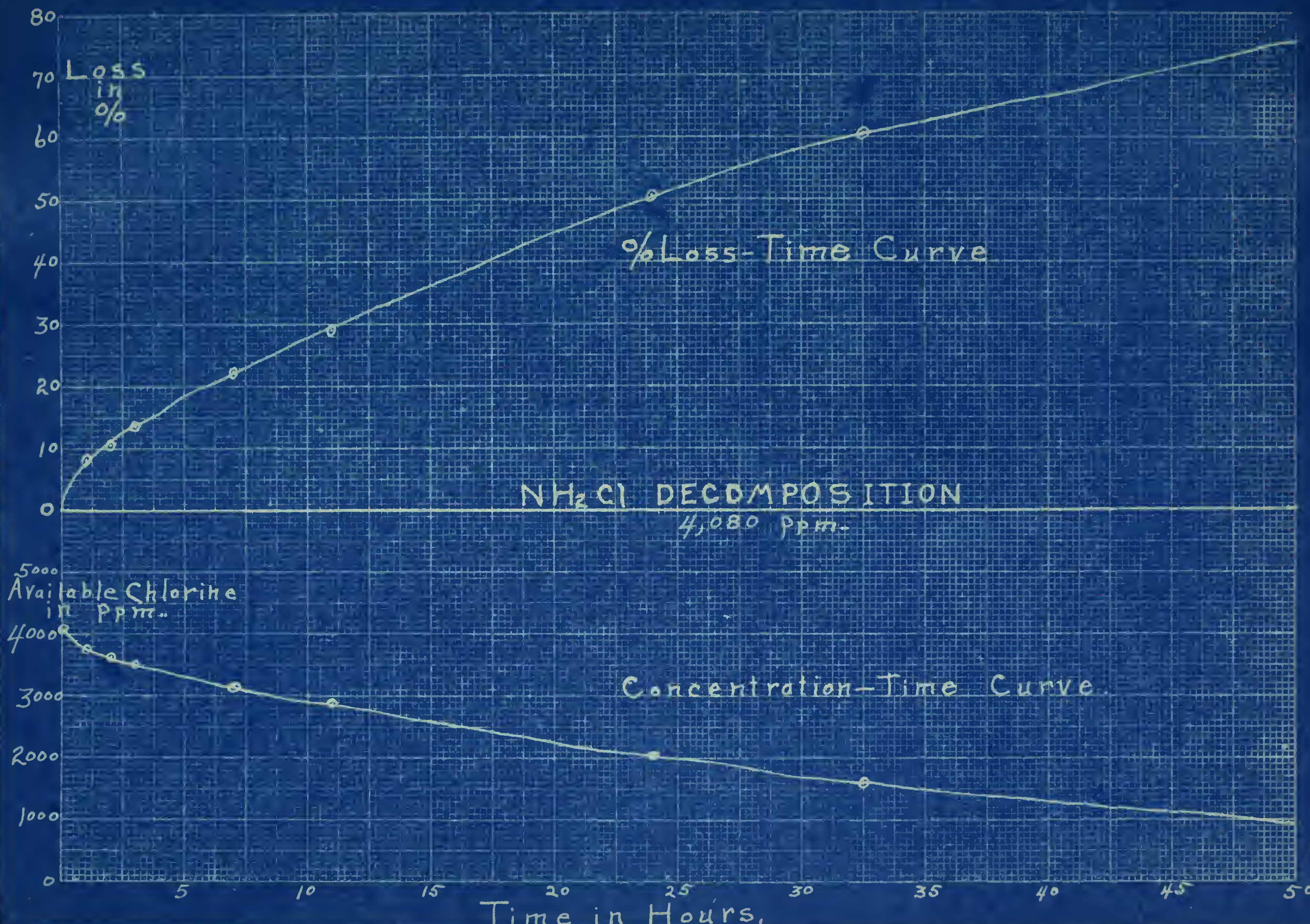

NH2Cl Decomposition
8,160 ppm
% Loss-Time Curve.
Loss in %.
0
10
20
30
40
50
60
70
80
90
100
5
10
15
20
25
30
35
40
45
50
Time in Hours.

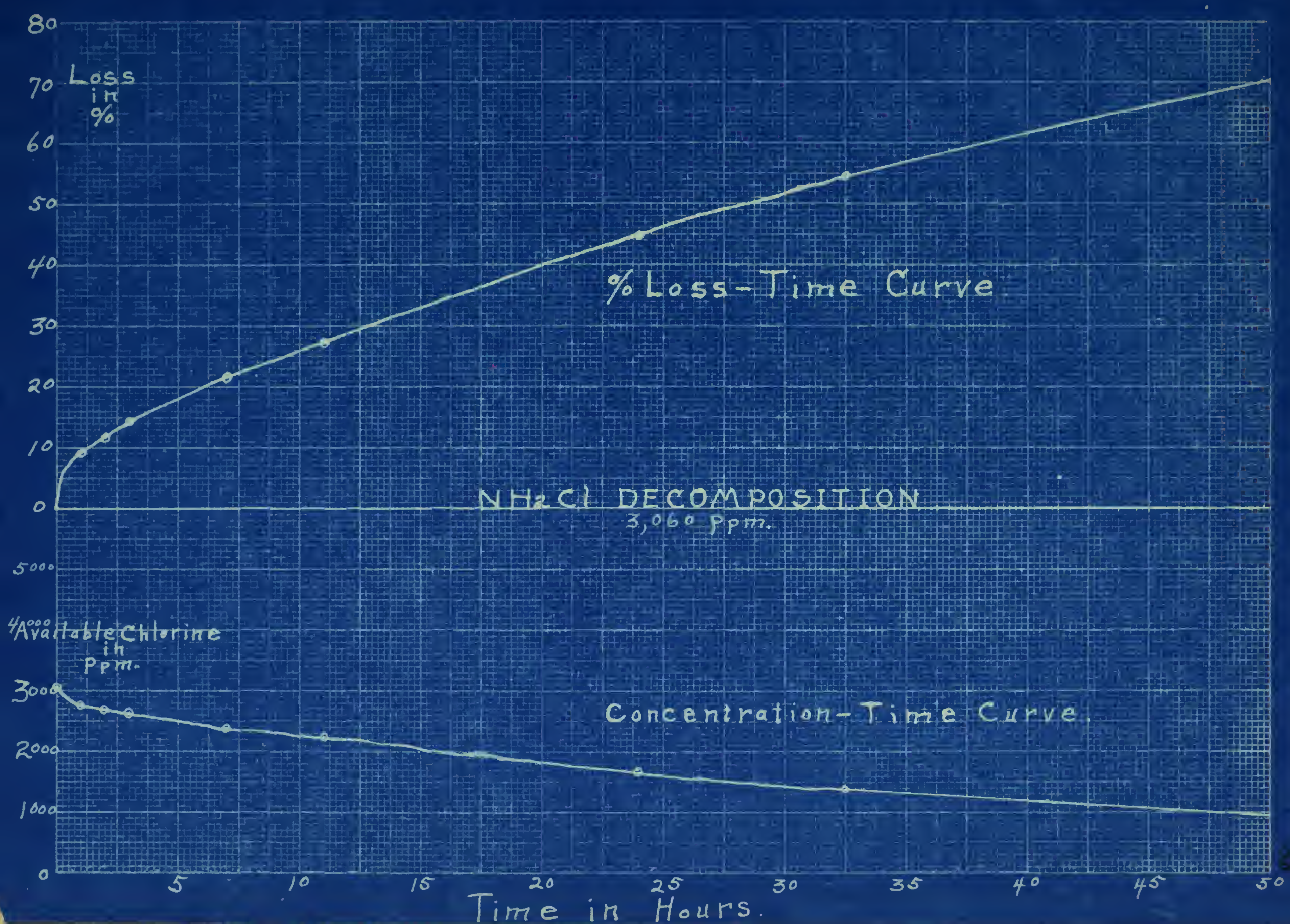

Available Chlorine
in
Ppm.
NH2Cl Decomposition
8,160 ppm.
Concentration - Time Curve.
8000
7000
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50
Time in Hours.

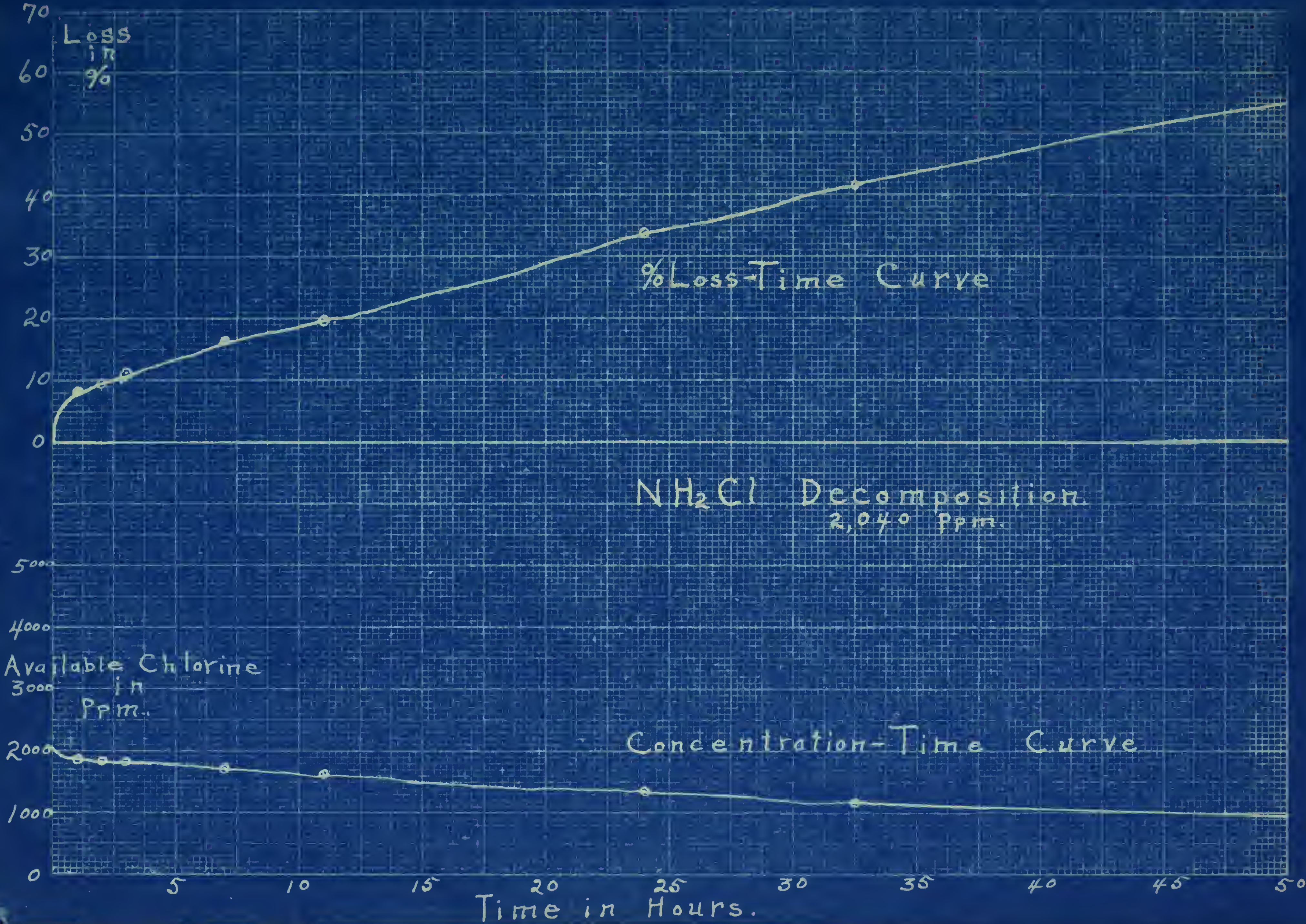


Loss in %
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
Time in Hours.
NH₂Cl Decomposition
6,120 ppm.
% Loss - Time Curve


Available Chlorine in Ppm.
NH2Cl Decomposition.
6,120 ppm.
Concentration-Time Curve
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50
Time in Hours.


NH₂Cl DECOMPOSITION
4,080 ppm.
% Loss-Time Curve
Concentration-Time Curve
Loss in %
Available Chlorine in ppm.
Time in Hours.
80
70
60
50
40
30
20
10
0
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50


NH₂Cl DECOMPOSITION
3,060 Ppm.
% Loss-Time Curve
Concentration-Time Curve.
Loss in %
Available Chlorine in Ppm.
Time in Hours.
80
70
60
50
40
30
20
10
0
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50



Loss in %
%Loss-Time Curve
NH2Cl Decomposition
2,040 ppm.
Available Chlorine in ppm.
Concentration-Time Curve
Time in Hours.

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